UNIVERSITY OF TORONTO
FACULTY OF ARTS AND SCIENCE

APRIL EXAMINATIONS 2012
CHM 139H1 S

Name (print): ____________________

Student No: ____________________ Demonstration Gp. No.: __________

DURATION: 3 HOURS **TOTAL MARKS = 75**

Calculators may be used but not shared. Programmable calculators may not be used. A **PERIODIC TABLE** and **USEFUL DATA** are attached to the back of the exam.

WHEN YOU RECEIVE YOUR EXAM PAPER AND COMPUTER ANSWER SHEET:

1. Write your name, student number and demonstrator group number on this page.
2. Write your last name and initials in the box provided at the top right of the computer answer sheet. Blacken the appropriate circles for your last name and initials.
3. Write your student number along the top of the student number box and blacken the circles which correspond to your student number.
4. In the box titled FORM, fill in the circle marked 'A'.

YOUR ANSWERS ARE TO BE RECORDED ON THE COMPUTER ANSWER SHEET AND ON THIS PAPER, BOTH OF WHICH MUST BE HANDED IN AT THE END OF THE EXAM.

PART A 24 MULTIPLE CHOICE QUESTIONS (36 marks)
PART B 4 SHORT ANSWER QUESTIONS (39 marks)

AT THE END OF THE EXAM:

Insert your computer answer sheet into your exam paper. Remain seated until all exam papers have been collected.

QUESTION (PART B)	**MARK**
1	/9
2	/9
3	/8
4	/13
TOTAL (PART B)	/39

TOTAL (PART A) = ______/36 **EXAM TOTAL =** ______/75

PART A: MULTIPLE CHOICE QUESTIONS

1. A compound containing chromium and silicon contains 73.52 mass percent chromium. Determine its empirical formula.

   a) $CrSi_3$
   b) Cr_2Si_3
   c) Cr_3Si
   d) Cr_3Si_2
   e) Cr_2Si

2. Which statement below is *incorrect*?

   a) There is a higher chance of finding an electron close to the nucleus in a 2s orbital than in a 2p orbital.
   b) For a 1s orbital, the electron probability density is highest at the nucleus.
   c) A 3s orbital has two spherical nodes.
   d) The radial probability distribution plot for a 1s orbital is highest at the nucleus.
   e) An s orbital does not have nodal planes.

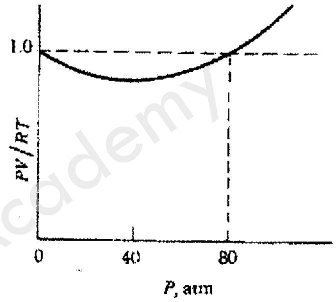
3. Electric power is measured in watts (1 W = 1 J/s). About 95% of the power output of an incandescent bulb is converted to heat and 5% to light. If 10% of that light shines on your chemistry text, how many photons per second shine on the book from a 75-W bulb? (Assume the photons have a wavelength of 550 nm).

   a) 1.5×10^{16} photons/s
   b) 1.0×10^{18} photons/s
   c) 3.0×10^{18} photons/s
   d) 1.0×10^{19} photons/s
   e) 2.1×10^{19} photons/s

4. The van der Waals equation of state for a nonideal gas can be rearranged to give:

$$\frac{PV}{RT} = \frac{V}{V-b} - \frac{a}{VRT}$$

for 1 mole of gas. The constants *a* and *b* are positive numbers. When applied to H_2 at 80K the equation gives the curve shown on the right. Which one of the following statements is correct?



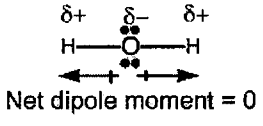
   a) At 40 atm the two terms $V/(V-b)$ and a/VRT are equal.
   b) At 0 atm the temperature is absolute zero.
   c) At 80 atm the two terms $V/(V-b)$ and a/VRT are equal.
   d) At 80 atm the gas has condensed.
   e) At a pressure greater than 80 atm, the term $V/(V-b)$ is greater than a/VRT.

5. Select the element with the most negative electron affinity:

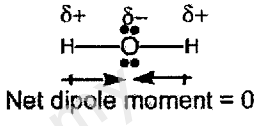
- a) H
- b) Li
- c) C
- d) F
- e) Ne

6. Which drawing best accounts for the polarity of water, H_2O, and the bond polarities that make a major contribution to the overall molecular polarity?

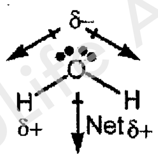
- a) Drawing (1)
- b) Drawing (2)
- c) Drawing (3)
- d) Drawing (4)
- e) None of the drawings are correct.



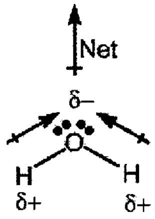
(1)



(2)



(3)



(4)

7. Find the vapour pressure lowering, ΔP, when 10.0 mL of glycerol ($C_3H_8O_3$) is added to 500 mL of water at 50°C. At this temperature, the vapour pressure of pure water is 92.5 torr and its density is 0.988 g/mL. The density of glycerol is 1.26 g/mL.

- a) 0.00498 torr
- b) 0.461 torr
- c) 16.4 torr
- d) 92.1 torr
- e) 95.2 torr

8. From the following list of aqueous solutions and water, select the one with the highest boiling point

- a) 1.0 *m* KNO_3
- b) 0.75 *m* NaCl
- c) 0.75 *m* $CuCl_2$
- d) 2.0 *m* $C_{12}H_{22}O_{11}$ (sucrose)
- e) pure water

9. The following statements about reaction rates are all true *with the exception of*:

- a) The rate depends on the concentration of one or more reactants
- b) The rate may be found from the disappearance of a reactant
- c) The rate always decreases as the reactants are consumed
- d) The rate may be increased by the addition of a catalyst
- e) The rate may be increased by raising the temperature

10. A certain reaction is known to follow the rate law $R = k[A]^2$. If the concentration of A fell from 0.125 M to 0.041 M in 67 seconds, the rate constant and half-life for this reaction are:

a) $0.10\ M^{-1}\ s^{-1}$ and 120 s
b) $0.17\ M^{-1}\ s^{-1}$ and 77 s
c) $0.24\ M^{-1}\ s^{-1}$ and 33 s
d) $0.38\ M^{-1}\ s^{-1}$ and 0.67 s
e) $0.52\ M^{-1}\ s^{-1}$ and 0.11 s

11. Ammonium hydrogen sulphide decomposes according to the following reaction:

$NH_4HS\ (s) \rightleftharpoons H_2S\ (g) + NH_3\ (g)$ $K_p = 0.11$ at 250 °C

If 1.00 mol of NH_4HS *(s)* is placed in an evacuated 2.00 L container and heated to 250 °C, what is the total gas pressure in the vessel at equilibrium?

a) 0.22 atm
b) 0.33 atm
c) 0.44 atm
d) 0.66 atm
e) 0.88 atm

12. Hypochlorous acid, HClO ($K_a = 2.9 \times 10^{-8}$) is a common disinfectant for swimming pools. It is prepared commercially by dissolving the sodium salt in water. If 20.0 g of NaClO is dissolved in sufficient pure water to produce 20.0 L of solution, the resulting pH is:

a) 3.04
b) 4.27
c) 8.51
d) 9.33
e) 9.83

13. A bottle of vinegar, which is a dilute solution of acetic acid ($K_a = 1.8 \times 10^{-5}$), is allowed to slowly evaporate at constant temperature until the volume of liquid has decreased by 15%. Assuming that none of the acetic acid evaporates, the fraction of the acid in its ionized form will:

a) Decrease as the volume decreases since $Q_c > K_a$
b) Decrease as the volume decreases since $Q_c < K_a$
c) Increase as the volume decreases since $Q_c > K_a$
d) Increase as the volume decreases since $Q_c < K_a$
e) Remain the same since K_a is constant at constant T

14. If a reaction has $\Delta H° < 0$ and $\Delta S° > 0$, the process is

a) spontaneous at all temperatures.
b) non-spontaneous at all temperatures.
c) spontaneous at higher temperatures.
d) spontaneous at lower temperatures.
e) very fast.

15. Consider the reaction: $N_2O_4\,(g) \rightleftharpoons 2NO_2\,(g)$
with the equilibrium constant $K_p = 0.113$ at 298K. In a certain experiment, the initial pressures are P=0.453 atm for N_2O_4 and P=0.122 atm for NO_2. What is ΔG for this reaction?

a) 3.06 kJ
b) 2.15 kJ
c) -3.06 kJ
d) -2.15 kJ
e) 1.72 kJ

16. The amount of heat required to heat 22 g of water from 25 ^{0}C to 100 ^{0}C is:

a) 6.9 kJ
b) 1.7 kJ
c) 0.48 kJ
d) 6.9 J
e) 0.8 J

17. Use the following data to calculate the boiling point of mercury

Hg *(l)*: $\Delta H_f° = 0$ (by definition), $S°$=77.4 J/(mol K)

Hg *(g)*: $\Delta H_f° = 60.78$ kJ/mole , $S°$=174.7 J/(mol K)

a) 0.625 K
b) 1600 K
c) 1600 C
d) 625 K
e) 160 L

18. Which of the following is the *best* shorthand notation describing a voltaic cell in which $Fe^{3+}(aq)$ is reduced to form $Fe^{2+}(aq)$ in one half-reaction, and copper metal is oxidized to form $Cu^{2+}(aq)$ in the other half-reaction?

a) Pt(*s*) | Fe^{2+} (*aq*), Fe^{3+} (*aq*) || Cu(*s*) | Cu^{2+}(*aq*)
b) Cu(*s*) | Cu^{2+}(*aq*) || Pt(*s*) | Fe^{3+} (*aq*), Fe^{2+} (*aq*)
c) Cu^{2+}(*aq*) | Cu(*s*) || Fe^{3+} (*aq*) | Fe^{2+} (*aq*)
d) Cu(*s*) | Cu^{2+}(*aq*) || Fe^{3+} (*aq*), Fe^{2+} (*aq*) | Pt(*s*)
e) MnO_4^-(*aq*), Mn^{2+}(*aq*) || Cu(*s*) | Cu^{2+}(*aq*)

19. An electrolytic cell consists of standard reference cell and a Cu/Cu^{2+} half cell. The voltage under standard conditions is:

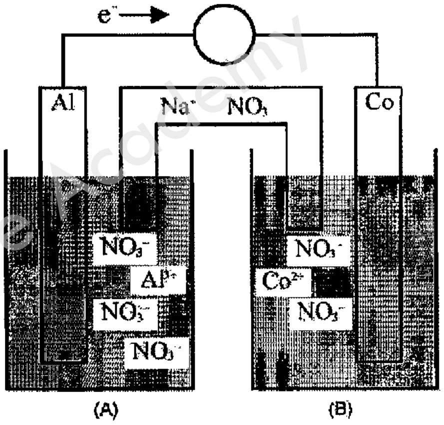
a) E = +0.68 V
b) E = -0.34 V
c) E= - 0.68 V
d) E = +0.34 V
e) E = -1.1 V

20. Consider the voltaic cell, Pt(*s*)| H_2(1 atm)| H^+(1 M)|| Cl^-(1 M)| Hg_2Cl_2 (*s*)| Hg(*l*).
Which one of the following changes to the cell would cause the cell potential to increase (i.e., become more positive)?

a) decrease the mass of Pt
b) increase the mass of Pt
c) decrease the pH
d) increase the pH
e) increase the mass of Hg

21. Identify the anode and cathode, and indicate the direction of Na^+ ion and NO_3^- ion flow from the salt bridge

a) Al is the anode and Co is the cathode; Na^+ ions flow into half-cell compartment (A) and NO_3^- ions flow into half-cell compartment (B).
b) Al is the anode and Co is the cathode; NO_3^- ions flow into half-cell compartment (A) and Na^+ ions flow into half-cell compartment (B).
c) Co is the anode and Al is the cathode; Na^+ ions flow into half-cell compartment (A) and NO_3^- ions flow into half-cell compartment (B)
d) Co is the anode and Al is the cathode; NO_3^- ions flow into half-cell compartment (A) and Na^+ ions flow into half-cell compartment (B).



22. What is the potential of a voltaic cell made up of Zn/Zn^{2+} and Cu/Cu^{2+} half cells at 25°C, if [Zn^{2+}]=1 M and [Cu^{2+}]=0.2 M

a) E = +1.1 V
b) E = +1.08 V
c) E = -0.42 V
d) E = -1.1 V
e) E = -1.6 V

23. Consider the cell

$$Ag(s) \mid Ag^{+}(aq)\ 5\times10^{-3}\,M \parallel Ag^{+}(aq)\ 0.15M \mid Ag(s)$$

What is the maximum work that the cell can perform at 298K?

a) 8.4 kJ
b) -8.4 kJ
c) 0 kJ
d) 4.2 kJ
e) 0.0436 V

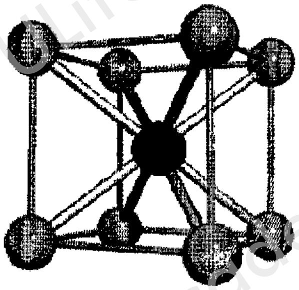
24. In the electrolysis of molten $CaCl_2$, a current of 1.12 A is passed through the cell for 3.0 h. What is the mass of Ca produced at the cathode?

a) 5.02 g
b) 1.26 g
c) 2.51 g
d) 10.0 g
e) 2.42×10^{5} g

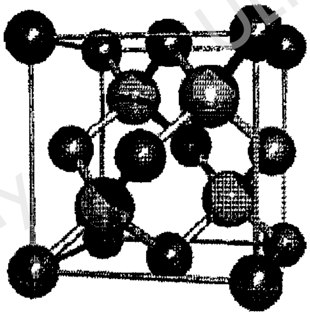
PART B. SHORT ANSWER QUESTIONS: Answers must be written in pen in the boxes provided. Be sure to show your work.

1. **(9 marks)** Below are three different crystal structures of a hypothetical AX type ceramic material.

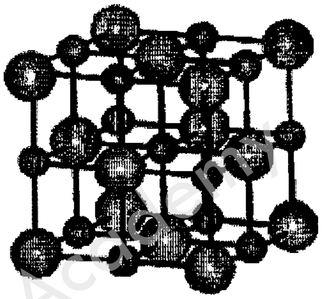
(a) For each unit cell shown below determine the number of atoms A (light) and X (dark) which are actually inside the unit cell.



SOLID A
A:
X:



SOLID B
A:
X:



SOLID C
A:
X:

(b) Material AX has a density of 2.10 g/cm^3 and a unit cell of cubic symmetry with a cell edge length of 0.57 nm. What is the weight of the unit cell?

(c) The atomic weights of the A and X elements in the material AX described in part (b) are 28.5 and 30.0 g/mol, respectively. On the basis of that information, calculate how many atoms of element A and element X are found in the unit cell of this solid.

(d) Based on your findings in parts (a)-(c), which of the crystal structures (A, B, or C in part (a)) is (are) possible for this material. Justify your choice.

2. (9 marks)

The majority of sulphur released into the atmosphere through the combustion of fossil fuels is in the form of sulphur dioxide, SO_2. The oxidation of atmospheric SO_2 and its subsequent involvement in acid rain has been studied extensively.

(a) One possible route for atmospheric oxidation is direct reaction with O_2, according to the reaction $2\ SO_2\ (g) + O_2\ (g) \rightarrow 2\ SO_3\ (g)$, for which $K_c = 1.28 \times 10^4$ at 852 K. What is K_c for the same reaction in the atmosphere at an average temperature of 222 K, given that $\Delta H = -98.9$ kJ/mol? **(Hint: use the van't Hoff relationship)**

(b) A great deal of atmospheric SO_2 oxidation actually occurs in the aqueous phase. What is the solubility of SO_2 in pure water exposed to a constant pressure of SO_2 $P_{SO2} = 1.00 \times 10^{-3}$ atm? Henry's constant for SO_2 is: $K_H = 1.242\ \text{M atm}^{-1}$.

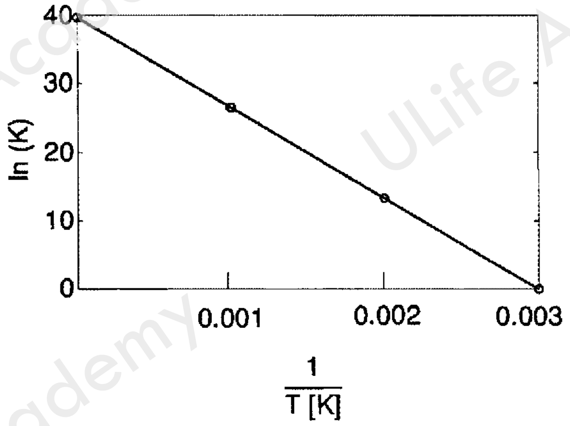
(c) When dissolved in water, SO_2 forms $H_2SO_3\ (aq)$, a diprotic acid. Use the value of solubility from (b) to calculate the pH of the resulting solution. What assumption do you need to make?

$$H_2SO_3\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + HSO_3^-\ (aq) \qquad K_{a1} = 1.32 \times 10^{-2}$$

$$HSO_3^-\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + SO_3^{2-}\ (aq) \qquad K_{a2} = 6.42 \times 10^{-8}$$

3. (8 marks)

The equilibrium constant for a hypothetical reaction was studied as a function of temperature. The results are plotted below.



(a) Consider the following relations: $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G° = -RT\ln K$

From the plot, determine the values of ΔH° and ΔS° for this process.

(b) What would be the major difference in the plot of ln(K) vs 1/T for an endothermic process, as opposed to an exothermic process?

(c) Is the process spontaneous at 500°C? Explain.

4. (13 marks)

Unlike fossil fuels, the burning of hydrogen gas does not contribute to atmospheric CO_2 levels, and so does not contribute to global warming. The cleanest fossil fuel to compare to a hydrogen fuel economy is propane.

(a) Taking the cell potential for the hydrolysis of liquid water ($2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$) (neutral *p*H) to be -1.23V, calculate the free energy associated with this reaction.

(b) Considering your answer from part (a), calculate the free energy that can be extracted from hydrogen gas, i.e. for the reaction: $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
Given: $H_2O(l) \rightarrow H_2O(g)$; $\Delta G^0 = 8.6$ kJ

(Hint: The cell potential of -1.23V refers to hydrolysis of $H_2O(l)$. You need to take into account the change from liquid to gas phase.)

(c) Using ΔG^0_f ($C_3H_8(g)$) = -24.5 kJ/mole, ΔG^0_f ($CO_2(g)$) = -394 kJ/mole, and ΔG^0_f ($H_2O(g)$) = -229 kJ/mole, calculate the maximum work that can be extracted from the *combustion* of 700 g of $C_3H_8(g)$ (approximately 1 liter of liquid propane) with oxygen under standard conditions.

(d) Calculate the mass of hydrogen gas needed to deliver the same energy as 1 liter of propane. Comment on the difference in energy stored per unit mass for hydrogen and fossil fuels.
<Let's hope we someday have a hydrogen economy.>

USEFUL EQUATIONS

$E=h\nu$ $\lambda=c/\nu$ $\lambda=h/m\nu$ $E_{photon}=h\nu_0 + E_k$ $E_n = -R_HZ^2/n^2$

$PV=nRT$ $(P+n^2a/V^2)(V-nb)=nRT$

$KE = ½ mu^2=3RT/(2N_A)$ $u_{rms} = (3RT/M)^{1/2}$

$\Delta T_b = K_bm$ $\Delta T_f = K_fm$ $\Pi=MRT$ $P_{solution}=X_{solvent}P_{solvent}$ $S_{gas}=K_HP_{gas}$

$ax^2 + bx + c = 0$ $x=\dfrac{-b\pm\sqrt{b^2-4ac}}{2a}$ $\ln(ab) = \ln(a) + \ln(b)$; $\ln(a/b) = -\ln(b/a)$

$K_p=K_c(RT)^{\Delta n}$; $\Delta n = c + d - (a + b)$ Arrhenius equation: $k = Ae^{-Ea/RT}$

First order reaction: $\ln\{[A]_0/[A]\} = kt$ $t_{1/2} = \ln2/k$

Second order reaction: $1/[A] - 1/[A]_0 = kt$ $t_{1/2} = 1/k[A]_0$

Zero order reaction: $[A]= -kt + [A]_0$ $t_{1/2} = [A]_0/2k$

$pH = -\log[H_3O^+]$ $pOH = -\log[OH^-]$ $pH + pOH = 14$ $K_a \times K_b = K_w$ $pH = pK_a + \log\dfrac{[base]}{[acid]}$

$q = nC\Delta T$ $w = -P\Delta V$ $\Delta E = q + w$ $\Delta H = \Delta E + P\Delta V$

$S = k\ln W$ $\Delta S = \dfrac{q}{T}$ $\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr}$

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\Delta H^\circ = \sum coeff_p \Delta H_f^\circ(pdts) - \sum coeff_r \Delta H_f^\circ(rcts)$$

$$\Delta S^\circ = \sum coeff_p S^\circ(pdts) - \sum coeff_r S^\circ(rcts)$$

$$\Delta G^\circ = \sum coeff_p \Delta G_f^\circ(pdts) - \sum coeff_r \Delta G_f^\circ(rcts)$$

$\Delta G = \Delta H - T\Delta S$ $\Delta G = \Delta G^\circ + RT\ln Q$ $\Delta G^\circ = -RT\ln K$ $\Delta G = -nFE$

$I = \dfrac{nC}{t}$ $E = E^\circ - \dfrac{RT}{nF}\ln Q$ $E = E^\circ - \dfrac{0.0592\ \text{V}}{n}\log Q$ (at 298.15 K)

PHYSICAL AND CHEMICAL CONSTANTS

Atomic mass unit	1 a.m.u. = $1.6605402 \times 10^{-27}$ kg
Mass of an electron	$m_e = 9.109 \times 10^{-31}$ kg
Mass of a neutron	$m_n = 1.674 \times 10^{-27}$ kg
Mass of a proton	$m_p = 1.672 \times 10^{-27}$ kg
Avogadro's number	$N_A = 6.0221367 \times 10^{23}$ mole^{-1}
Boltzmann's constant	$k = 1.380658 \times 10^{-23}$ J K^{-1}
Faraday's constant	$F = 9.6485309 \times 10^{4}$ C mole^{-1}
Fundamental unit charge	$e = 1.60217733 \times 10^{-19}$ C
Gas constant	$R = 8.314510$ J mole^{-1} K^{-1}
	= 0.082058 L atm mole^{-1} K^{-1}
Heat capacity of water	C = 4.184 J g^{-1} K^{-1}
	= 75.4 J mole^{-1} K^{-1}
Planck's constant	$h = 6.6260755 \times 10^{-34}$ J s
Rydberg's constant	$R_H = 2.1798 \times 10^{-18}$ J
	$= 1.097 \times 10^{-2}$ nm^{-1}
Speed of light	$c = 2.99792458 \times 10^{8}$ m s^{-1}
Zero point	0°C = 273.15 K
K_w of H_2O at 25°C	$K_w = 1.00 \times 10^{-14}$
Pi	$\pi = 3.1415927$

CONVERSION FACTORS

1 atmosphere (atm) = 1.01325×10^{5} Pa (N m^{-2}) = 760.0 mm Hg (torr) = 1.01325 bar

1 calorie (cal) = 4.184 joules (J)

1 debye (D) = 3.335617×10^{-30} C m

1 eV/particle = 96.485 kJ mole^{-1} = 23.061 kcal mole^{-1}

1 eV = 1.602×10^{-19} J = 8067 cm^{-1}

1 V = 1 J/C

1 A = 1 C/s

1 kcal mole^{-1} = 4.184 kJ mole^{-1} = 349.73 cm^{-1}

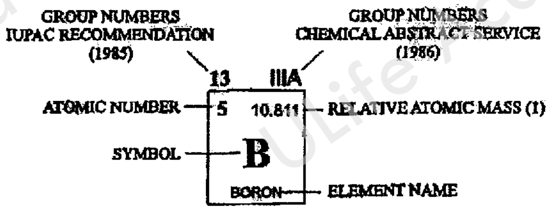
1 kJ mole^{-1} = 0.23901 kcal mole^{-1} = 83.591 cm^{-1}

1 L atm = 101.325 J = 24.217 cal

ln x = 2.3026 log x

PERIODIC TABLE OF THE ELEMENT

http://www.ktf-split.hr/pe



	GROUP								VIIIB						
PERIOD	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9	10	11 IB	12 IIB	13 IIIA	14 IVA	15 V
1	1 1.0079 **H** HYDROGEN														
2	3 6.941 **Li** LITHIUM	4 9.0122 **Be** BERYLLIUM											5 10.811 **B** BORON	6 12.011 **C** CARBON	7 14.00 **N** NITROGE
3	11 22.990 **Na** SODIUM	12 24.305 **Mg** MAGNESIUM											13 26.982 **Al** ALUMINIUM	14 28.086 **Si** SILICON	15 30.97 **P** PHOSPHOR
4	19 39.098 **K** POTASSIUM	20 40.078 **Ca** CALCIUM	21 44.956 **Sc** SCANDIUM	22 47.867 **Ti** TITANIUM	23 50.942 **V** VANADIUM	24 51.996 **Cr** CHROMIUM	25 54.938 **Mn** MANGANESE	26 55.845 **Fe** IRON	27 58.933 **Co** COBALT	28 58.693 **Ni** NICKEL	29 63.546 **Cu** COPPER	30 65.39 **Zn** ZINC	31 69.723 **Ga** GALLIUM	32 72.64 **Ge** GERMANIUM	33 74.92 **As** ARSENIC
5	37 85.468 **Rb** RUBIDIUM	38 87.62 **Sr** STRONTIUM	39 88.906 **Y** YTTRIUM	40 91.224 **Zr** ZIRCONIUM	41 92.906 **Nb** NIOBIUM	42 95.94 **Mo** MOLYBDENUM	43 (98) **Tc** TECHNETIUM	44 101.07 **Ru** RUTHENIUM	45 102.91 **Rh** RHODIUM	46 106.42 **Pd** PALLADIUM	47 107.87 **Ag** SILVER	48 112.41 **Cd** CADMIUM	49 114.82 **In** INDIUM	50 118.71 **Sn** TIN	51 121.7 **Sb** ANTIMON
6	55 132.91 **Cs** CAESIUM	56 137.33 **Ba** BARIUM	57-71 La-Lu Lanthanide	72 178.49 **Hf** HAFNIUM	73 180.95 **Ta** TANTALUM	74 183.84 **W** TUNGSTEN	75 186.21 **Re** RHENIUM	76 190.23 **Os** OSMIUM	77 192.22 **Ir** IRIDIUM	78 195.08 **Pt** PLATINUM	79 196.97 **Au** GOLD	80 200.59 **Hg** MERCURY	81 204.38 **Tl** THALLIUM	82 207.2 **Pb** LEAD	83 208.9 **Bi** BISMUTH
7	87 (223) **Fr** FRANCIUM	88 (226) **Ra** RADIUM	89-103 Ac-Lr Actinide	104 (261) **Rf** RUTHERFORDIUM	105 (262) **Db** DUBNIUM	106 (266) **Sg** SEABORGIUM	107 (264) **Bh** BOHRIUM	108 (277) **Hs** HASSIUM	109 (268) **Mt** MEITNERIUM	110 (281) **Uun** UNUNNILIUM	111 (272) **Uuu** UNUNUNIUM	112 (285) **Uub** UNUNBIUM		114 (289) **Uuq** UNUNQUADIUM	

LANTHANIDE

6	57 138.91 **La** LANTHANUM	58 140.12 **Ce** CERIUM	59 140.91 **Pr** PRASEODYMIUM	60 144.24 **Nd** NEODYMIUM	61 (145) **Pm** PROMETHIUM	62 150.36 **Sm** SAMARIUM	63 151.96 **Eu** EUROPIUM	64 157.25 **Gd** GADOLINIUM	65 158.93 **Tb** TERBIUM	66 162.50 **Dy** DYSPROSIUM	67 164.93 **Ho** HOLMIUM	68 167.2 **Er** ERBIUM

ACTINIDE

7	89 (227) **Ac** ACTINIUM	90 232.04 **Th** THORIUM	91 231.04 **Pa** PROTACTINIUM	92 238.03 **U** URANIUM	93 (237) **Np** NEPTUNIUM	94 (244) **Pu** PLUTONIUM	95 (243) **Am** AMERICIUM	96 (247) **Cm** CURIUM	97 (247) **Bk** BERKELIUM	98 (251) **Cf** CALIFORNIUM	99 (252) **Es** EINSTEINIUM	100 (25 **Fm** FERMIUM

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Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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Standard Reduction Potentials (in Volts), $25^{o}C$

Reaction	$E^{o}(V)$
$Cl_2 + 2e^- \text{--->} 2Cl^-$	+1.36
$O_2 + 4H^+ + 4e^- \text{--->} 2H_2O$	+1.23
$Br_2 + 2e^- \text{--->} 2Br^-$	+1.07
$Fe^{3+} + e^- \text{--->} Fe^{2+}$	+0.77
$Ag^+ + e^- \text{--->} Ag$	+0.80
$I_2 + 2e^- \text{--->} 2I^-$	+0.54
$Cu^+ + e^- \text{--->} Cu$	+0.52
$Fe(CN)_6{}^{3-} + e^- \text{--->} Fe(CN)_6{}^{4-}$	+0.36
$Cu^{2+} + 2e^- \text{--->} Cu$	+0.34
$Cu^{2+} + e^- \text{--->} Cu^+$	+0.15
$Sn^{4+} + 2e^- \text{--->} Sn^{2+}$	+0.15
$2H^+ + 2e^- \text{--->} H_2$	0.00
$Fe^{3+} + 3e^- \text{--->} Fe$	-0.04
$Pb^{2+} + 2e^- \text{--->} Pb$	-0.13
$Ni^{2+} + 2e^- \text{--->} Ni$	-0.26
$Fe^{2+} + 2e^- \text{--->} Fe$	-0.41
$Cr^{3+} + 3e^- \text{--->} Cr$	-0.74
$Zn^{2+} + 2e^- \text{--->} Zn$	-0.76
$2H_2O + 2e^- \text{--->} H_2(g) + 2OH^-$	-0.83
$V^{2+} + 2e^- \text{--->} V$	-1.18
$Mn^{2+} + 2e^- \text{--->} Mn$	-1.18
$Al^{3+} + 3e^- \text{--->} Al$	-1.66
$Mg^{2+} + 2e^- \text{--->} Mg$	-2.37